THE IMPORTANCE OF SOIL ECOLOGY IN SUSTAINABLE AGRICULTURE

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SUSTAINABLE AGRICULTURE

- INTEGRATED SYSTEMS OF AGRICULTURAL PRODUCTION WHICH ARE LESS DEPENDENT ON HIGH INPUTS OF ENERGY AND SYNTHETIC CHEMICALS, AND MORE MANAGEMENT INTENSIVE THAN CONVENTIONAL AGRICULTURE. THESE MAINTAIN CROP PRODUCTIVITY, QUALITY AND YIELDS, ARE ECOLOGICALLY SUSTAINABLE, AND PROTECT THE ENVIRONMENT AND NATURAL RESOURCES.

SOIL ECOLOGY

- THE STUDY OF RELATIONSHIPS BETWEEN LIVING ORGANISMS AND THE ENVIRONMENTAL CONDITIONS IN THE SOIL IN WHICH THEY LIVE.

THE IMPORTANCE OF SOIL ECOLOGY IN SUSTAINABLE AGRICULTURE

- THE CONCEPTS OF SUSTAINABLE AGRICULTURE
- INPUTS INTO SUSTAINABLE AGRICULTURE
- THE ROLE OF SOIL ECOLOGY AND ITS POTENTIAL INPUTS INTO SUSTAINABLE AGRICULTURAL SYSTEMS
- A CASE STUDY: THE ROLE OF AGRICULTURAL VERMICOMPOSTING IN SUSTAINABLE AGRICULTURE

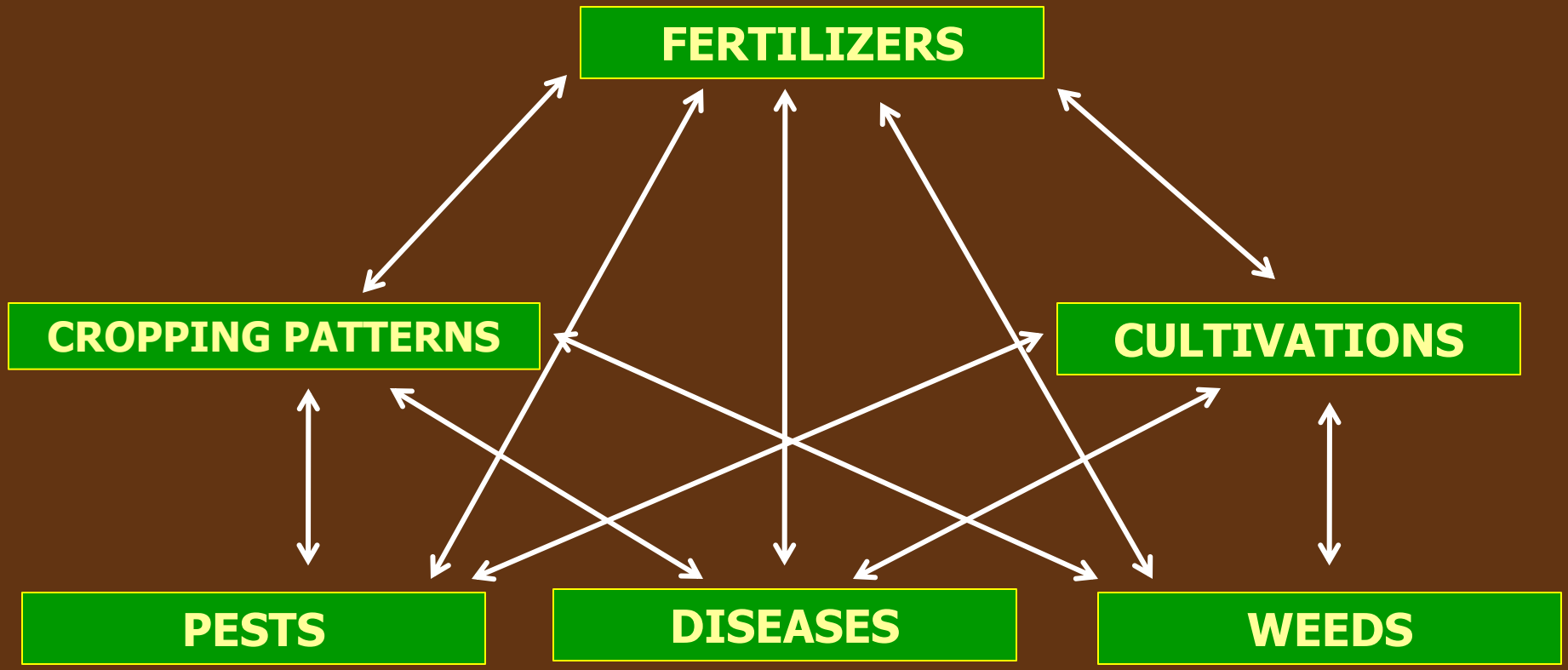
MAIN INPUTS INTO CONVENTIONAL AGRICULTURAL SYSTEMS

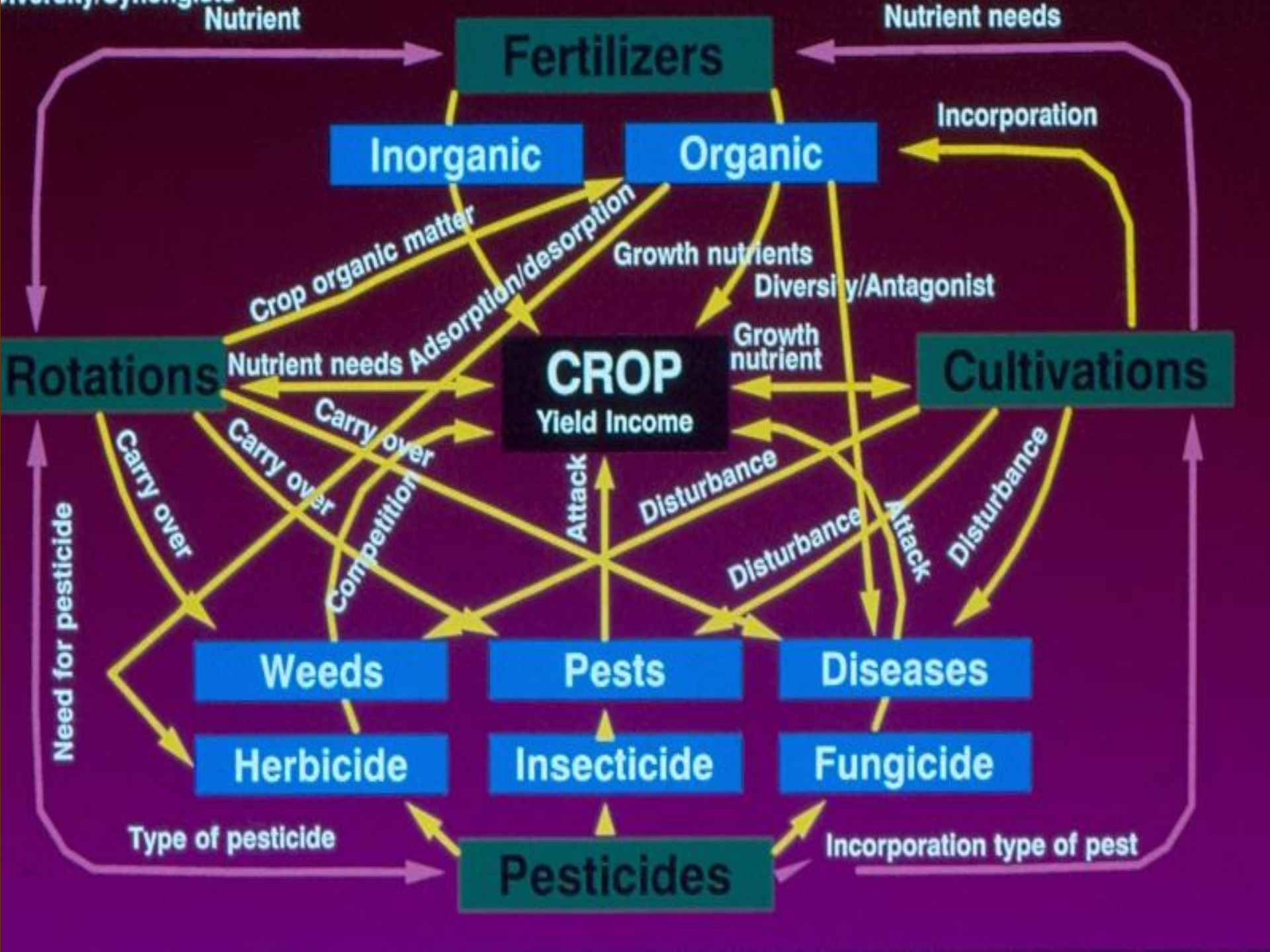
INPUTS	PRACTICES
FERTILITY	INORGANIC FERTILIZERS
CULTIVATIONS	DEEP PLOWING OR NO TILL
CROPPING	MONOCULTURE OR BICULTURE
PEST DISEASE & WEED CONTROL	ROTATIONS INSECTICIDES FUNGICIDES HERBICIDES NEMATICIDES

MAIN INPUTS INTO SUSTAINABLE AGRICULTURE SYSTEMS

INPUT	PRACTICES
FERTILITY	ORGANIC MINIMAL INORGANIC FERTILIZERS- INTEGRATED FERTILIZER MANAGEMENT
CULTIVATIONS	CONSERVATION TILLAGE OR NO TILL
CROPPING	ROTATIONS AND/OR CROPPING PATTERNS
PEST DISEASE & WEED CONTROL	ORGANIC MINIMAL PESTICIDES- INTEGRATED PEST MANAGEMENT

INTERACTIONS BETWEEN MAJOR INPUTS INTO AGRICULTURAL SYSTEMS




Nutrient
Nutrient needs
Fertilizers
Incorporation
Inorganic
Organic
Crop organic matter
Adsorption/desorption
Growth nutrients
Diversity/Antagonist
Rotations
Nutrient needs
CROP
Yield Income
Growth nutrient
Cultivations
Carry over
Carry over
Carry over
Competition
Attack
Disturbance
Disturbance
Attack
Disturbance
Need for pesticide
Weeds
Pests
Diseases
Herbicide
Insecticide
Fungicide
Type of pesticide
Pesticides
Incorporation type of pest

THE INTEGRATION OF ECOLOGICAL INPUTS INTO SUSTAINABLE AGRICULTURAL SYSTEMS

- MAXIMUM PROVISION OF NUTRIENTS FROM ORGANIC SOURCES
- MAINTENANCE OF ECOLOGICAL INTEGRITY IN SOILS THROUGH MINIMUM CULTIVATIONS
- MAXIMIZATION OF BIODIVERSITY THROUGH:
  - ROTATIONS
  - UNDERSOWING
  - STRIP CROPPING
  - CATCH CROPS
- MAXIMIZATION OF BIOLOGICAL SUPPRESSION OF PESTS AND PATHOGENS THROUGH:
  - ORGANIC MATTER
  - ALLELOPATHY
  - ENCOURAGEMENT OF PREDATORS AND PARASITES
  - RELEASE OF NATURAL ENEMIES

THE ROLE OF SOIL ECOLOGY

- ORGANIC MATTER BREAKDOWN
- SOIL-INHABITING INVERTEBRATES
- SOIL MICROORGANISMS
- INTERACTIONS BETWEEN INVERTEBRATES AND MICROORGANISMS
- FOOD WEBS IN SOIL
- SOIL ECOLOGICAL OUTPUTS
- FACILITATION OF NUTRIENT RECYCLING

NUMBERS AND BIOMASS OF SOIL-INHABITING INVERTEBRATES

TYPE OF ORGANISM	NO. M^{-2}	KG. HA^{-1}
PROTOZOA	10^9-10^{10}	20-200
NEMATODA (EELWORMS)	10^6-10^7	10-150
ACARINA (MITES)	10^3-10^5	5-150
COLLEMBOLA (SPRINGTAILS)	10^3-10^5	5-150
EARTHWORMS	10-10^3	100-5,000
OTHERS	10^2-10^4	10-100

NUMBERS AND BIOMASS OF SOIL MICROORGANISMS IN SOIL

TYPE OF ORGANISM	NO. M^{-2}	KG. HA^{-1}
BACTERIA	10^{13}-10^{14}	400-5,000
ACTINOMYCETES	10^{12}-10^{13}	400-5,000
FUNGI	10^{10}-10^{11}	1,000-15,000
ALGAE	10^{9}-10^{10}	10-500

SOIL INVERTEBRATES IMPORTANT IN ORGANIC MATTER BREAKDOWN

- **EARTHWORMS -OLIGOCHAETES**
- **MILLIPEDES -DIPLOPODA**
- **WOODLICE -ISOPODA**
- **MITES -ACARINA**
- **INSECTS -INSECTA**
- **SPRINGTAILS -COLLEMBOLA**
- **TERMITES -ISOPTERA**
- **ANTS -HYMENOPTERA**
- **BEETLES -COLEOPTERA**
- **FLY LARVAE -DIPTERA**
- **CATERPILLARS -COLEOPTERA**

SOIL INVERTEBRATES THAT CAN BE CROP PESTS

- **NEMATODES** **-NEMATODA**
- **POT WORMS** **-ENCHYTRAEIDAE**
- **GARDEN CENTIPEDES** **-SYMPHYLA**
- **MILLIPEDES** **-DIPLOPODA**
- **MOLLUSCS** **-GASTROPODA**
  - **SLUGS**
  - **SNAILS**
- **MITES** **-ACARINA**
- **SPRINGTAILS** **-COLLEMBOLA**
- **INSECTS** **-INSECTA**
  - **ANTS** **-HYMENOPTERA**
  - **TERMITES** **-ISOPODA**
  - **BEETLES** **-COLEOPTERA**
  - **FLY LARVAE** **-DIPTERA**
  - **CATERPILLARS** **-LEPIDOPTERA**
  - **THRIPS** **-THYSANOPTERA**

SOIL INVERTEBRATES THAT CAN BE PREDATORS OR PARASITES OF PESTS

- **NEMATODES** **-NEMATODA**
- **CENTIPEDES** **-CHILOPODA**
- **MITES** **-ACARINA (GAMASIDAE)**
- **SPIDERS** **-ARANEAE**
- **SCORPIONS** **-SCORPIONIDA**
- **PSEUDOSCORPIONS** **-PSEUDOSCORPIONES**
- **INSECTS** **-INSECTA**
  - **BEETLES** **-COLEOPTERA**
  - **TERMITES (SOLDIERS)** **-ISOPTERA**
  - **FLIES** **-DIPTERA**
  - **WASPS** **-HYMENOPTERA**

FUNCTIONS OF SOIL-INHABITING INVERTEBRATES

ORGANIC MATTER DECOMPOSERS	PESTS	PREDATORS OF PESTS
PROTOZOA	---------	--------
NEMATODES	NEMATODES	NEMATODES
ENCHYTRAEIDAE	ENCHYTRAEIDAE	--------
SYMPHYLA	SYMPHYLA	SYMPHYLA
WOODLICE	---------	---------
MILLIPEDES	MILLIPEDES	----------
----------	---------	CENTIPEDES
MOLLUSCS	MOLLUSCS	---------
EARTHWORMS	EARTHWORMS	---------
MITES	MITES	MITES
COLLEMBOLA	COLLEMBOLA	---------
INSECTS	INSECTS	INSECTS

EFFECTS OF SOIL ORGANISMS ON CROP PRODUCTIVITY

- BREAKDOWN OF ORGANIC MATTER
- RELEASE OF NUTRIENTS IN AVAILABLE FORM
- PHYSICAL SOIL TURNOVER: ESPECIALLY IMPORTANT UNDER NO TILL
- IMPROVED SOIL AERATION
- BETTER DRAINAGE
- INCREASED WATER-HOLDING CAPACITY
- PEST AND DISEASE SUPPRESSION

A CASE STUDY: THE ROLE OF VERMICOMPOSTING IN SUSTAINABLE AGRICULTURE

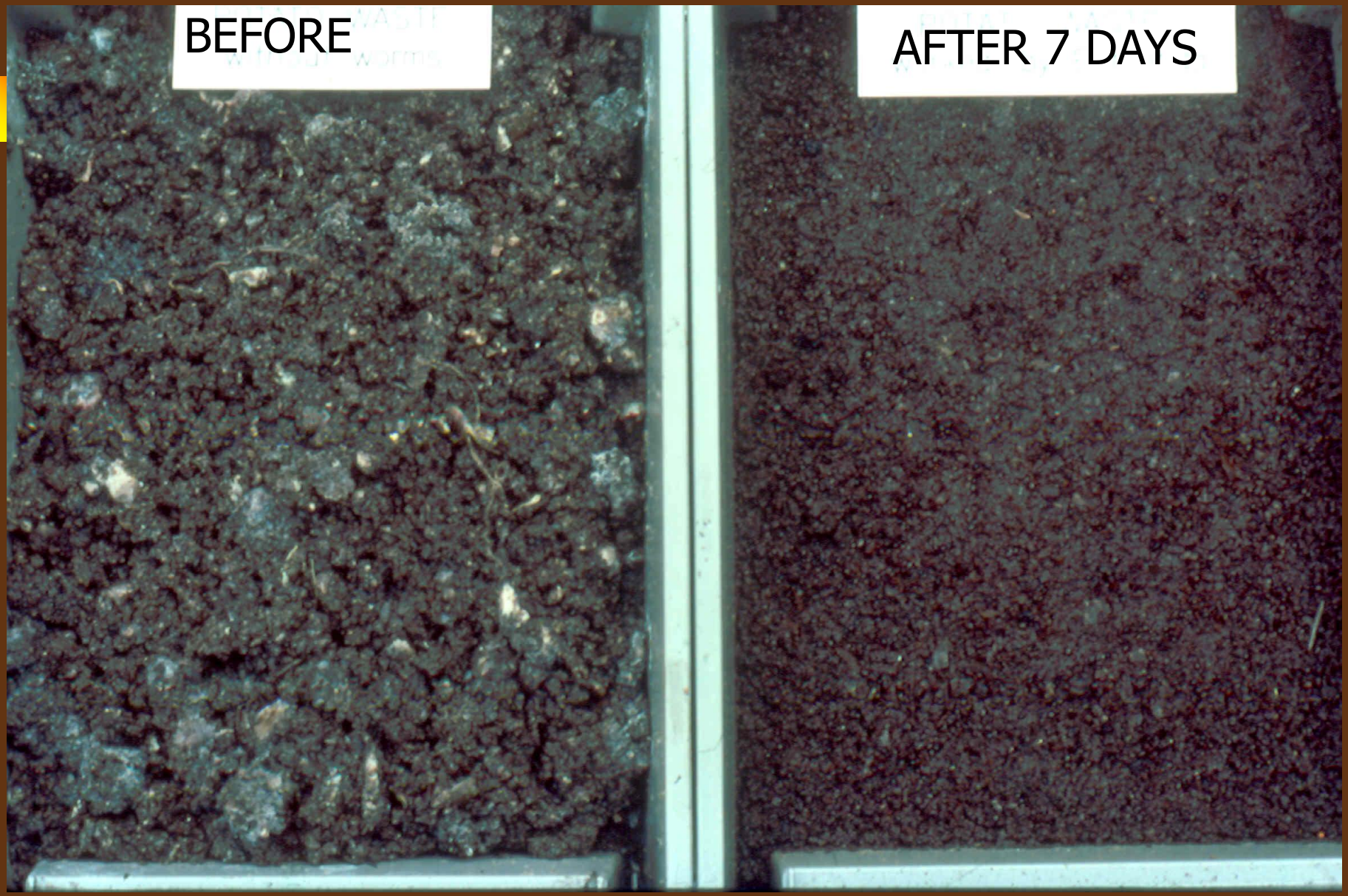
- EARTHWORMS
- PRINCIPLES OF VERMICOMPOSTING
- METHODS OF VERMICOMPOSTING
- EFFECTS ON CROP GROWTH GERMINATION AND YIELDS
- EFFECTS ON PLANT PATHOGENS
- EFFECTS ON PLANT PARASITIC NEMATODES
- EFFECTS ON ARTHROPOD PESTS
- ECONOMICS

EARTHWORMS

Earthworms are segmented invertebrates that inhabit soils and organic waste. They are hermaphrodite and usually reproduce by mating, each partner fertilizing the other. After mating they retract their bodies through the “saddle” or clitellum and pass it over their heads. Each cocoon contains one or more eggs and can survive adverse conditions, hatching when environmental conditions are favorable.

They take one to eight months to become sexually mature and continue to reproduce at regular intervals. They require moisture and aerobic conditions for survival and reproduction.

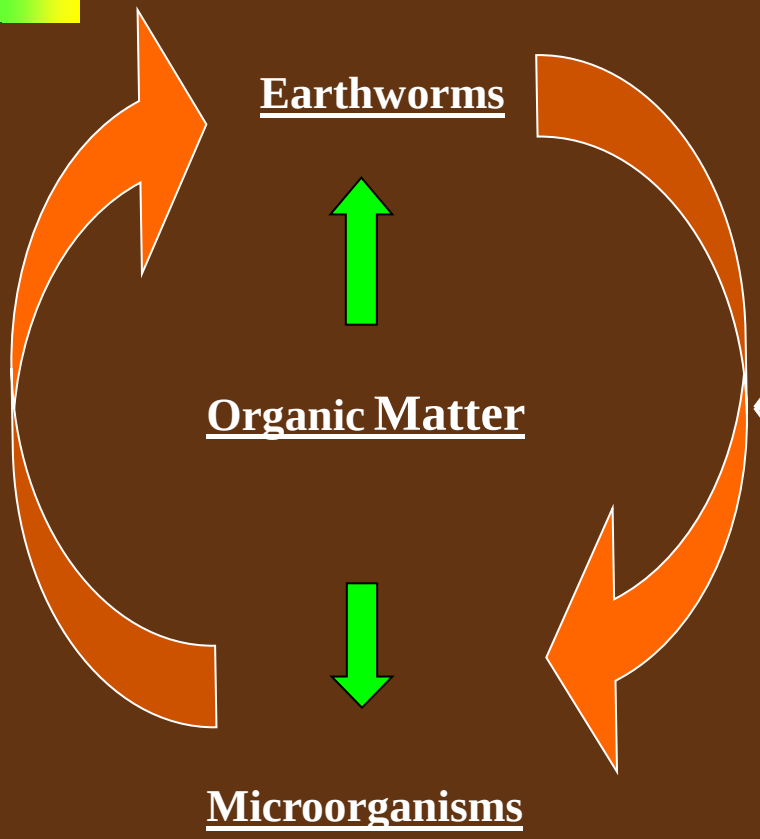
BREAKDOWN OF POTATO WASTES



VERMICOMPOSTS

Vermicomposts are organic materials, broken down by interactions between earthworms and microorganisms, in a mesophilic process (up to 25 ^{o}C), to produce fully-stabilized organic soil amendments with low C:N ratios. They have a high and diverse microbial and enzymatic activity, fine particulate structure, good moisture-holding capacity, and contain nutrients such as N,K, P, Ca and Mg in forms readily taken up by plants. They contain plant growth hormones and humic acids which act as plant growth regulators.

POTENTIAL INTERACTIONS BETWEEN EARTHWORMS & MICROORGANISMS IN VERMICOMPOSTS



Mineralization
Plant-Available Mineral Nutrients
N, P, K, Ca, Mg and Micronutrients

Phytohormone-like Plant Growth Regulators
Auxins, Cytokinins, Gibberellins

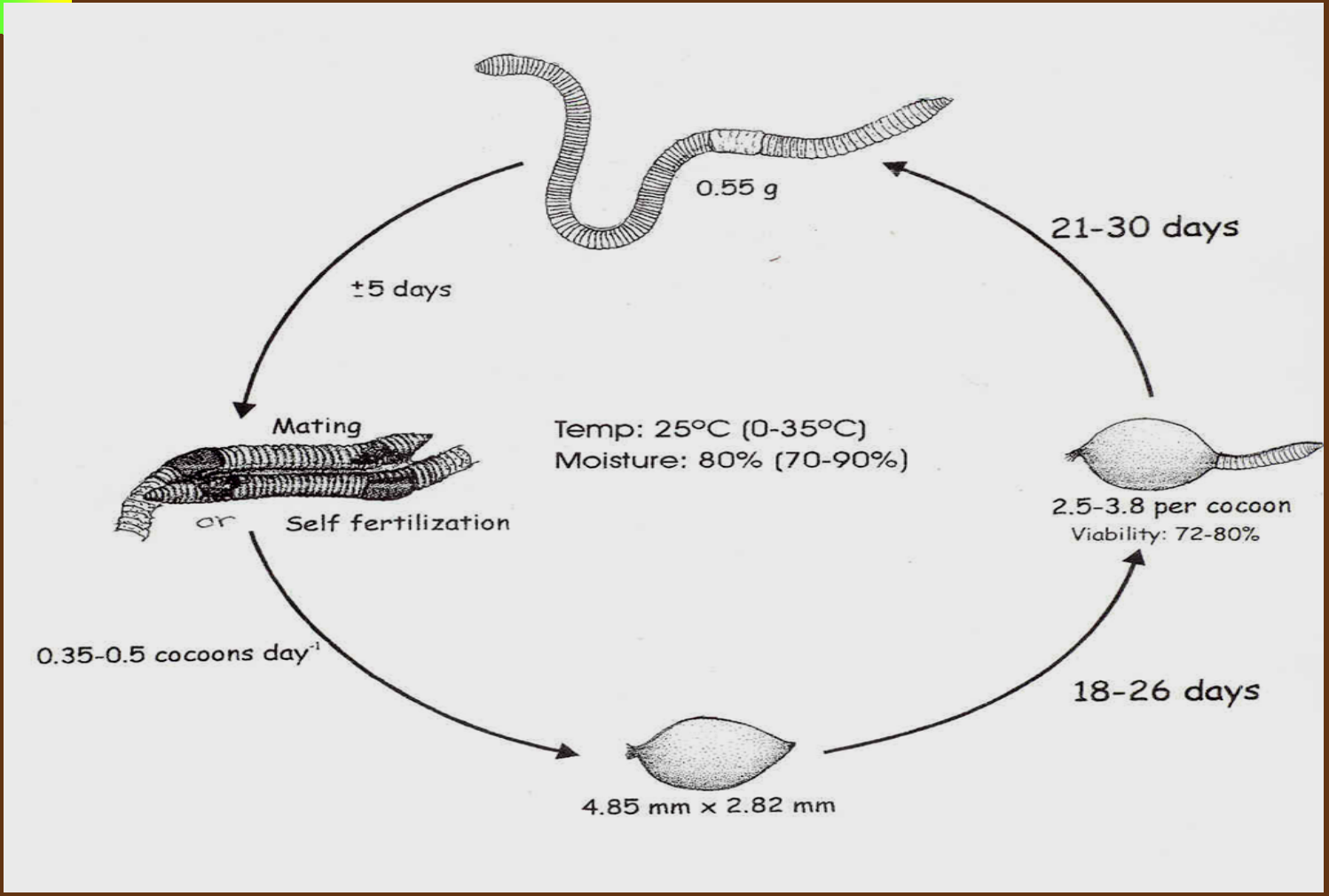
Other Plant-Growth Influencing Substances
Humic materials
Free Enzymes
Allelopathic agents

Plant Disease and Nematode Suppression

PRINCIPLES OF VERMICOMPOSTING

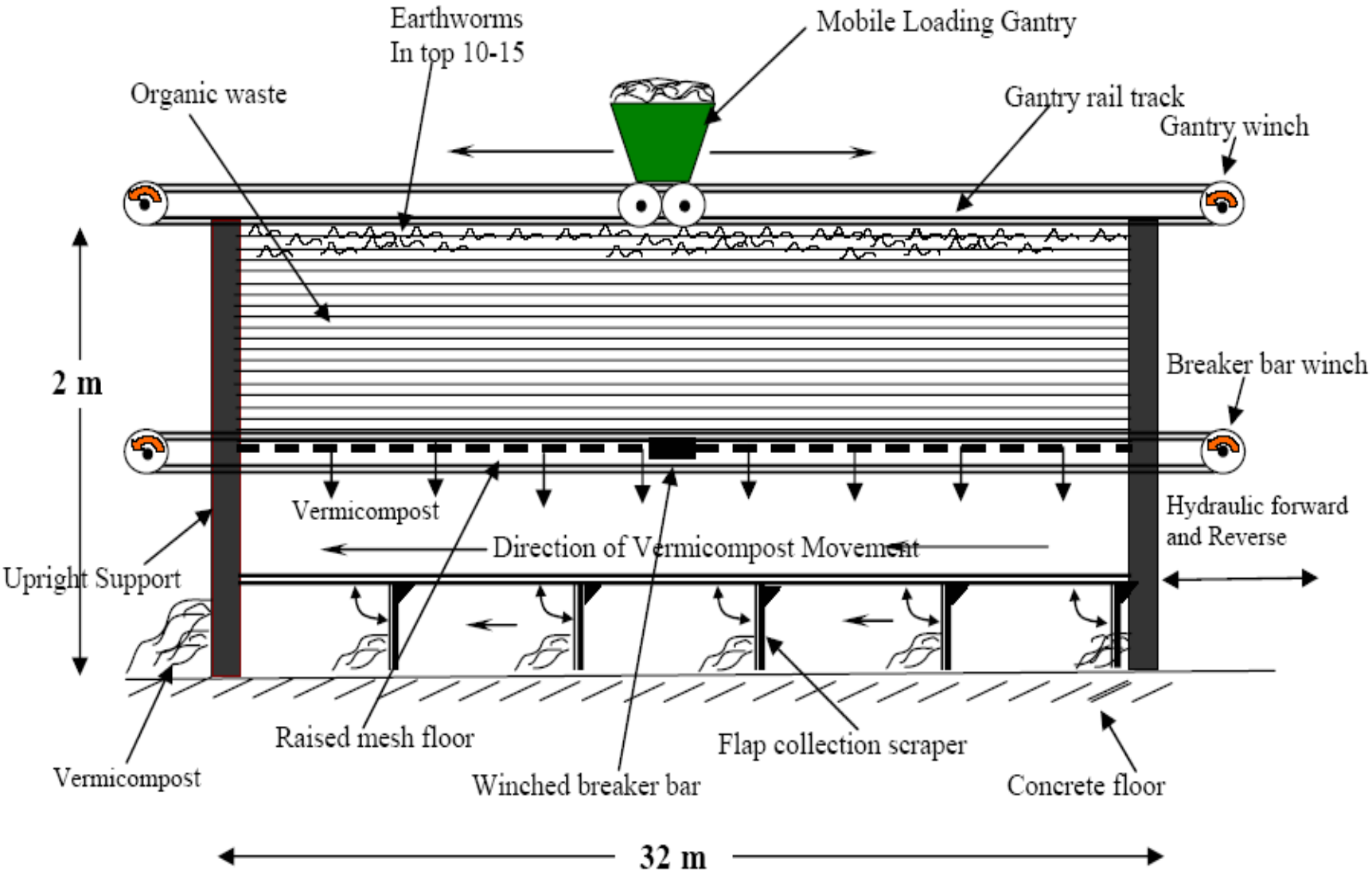
- Species of organic waste-consuming earthworms such as *Eisenia fetida* and *Eudrilus eugeniae* are used
- Temperature should be maintained at 20-25 ^{0}C
- Moisture content should be 75% - 90%
- Organic materials are added to systems in thin layers (2.5-5.0 cm)
- Earthworms require aerobic conditions and remain in the top 10-15 cm of a system – moving up as new organic matter is added to the surface

LIFE CYCLE OF *EISENIA FETIDA*



METHODS OF VERMICOMPOSTING

METHOD	**LOCATION**
WINDROWS	OUTDOOR, INDOOR
WEDGE SYSTEMS	OUTDOOR, INDOOR
BATCH SYSTEMS	INDOOR
DOMESTIC SYSTEMS	INDOOR
CONTINUOUS FLOW REACTORS	INDOOR
- MANUAL	
- AUTOMATED CONTINUOUS FLOW	


Earthworms
In top 10-15
Mobile Loading Gantry
Organic waste
Gantry rail track
Gantry winch
2 m
Breaker bar winch
Vermicompost
Hydraulic forward
and Reverse
Direction of Vermicompost Movement
Upright Support
Raised mesh floor
Flap collection scraper
Vermicompost
Winched breaker bar
Concrete floor
32 m

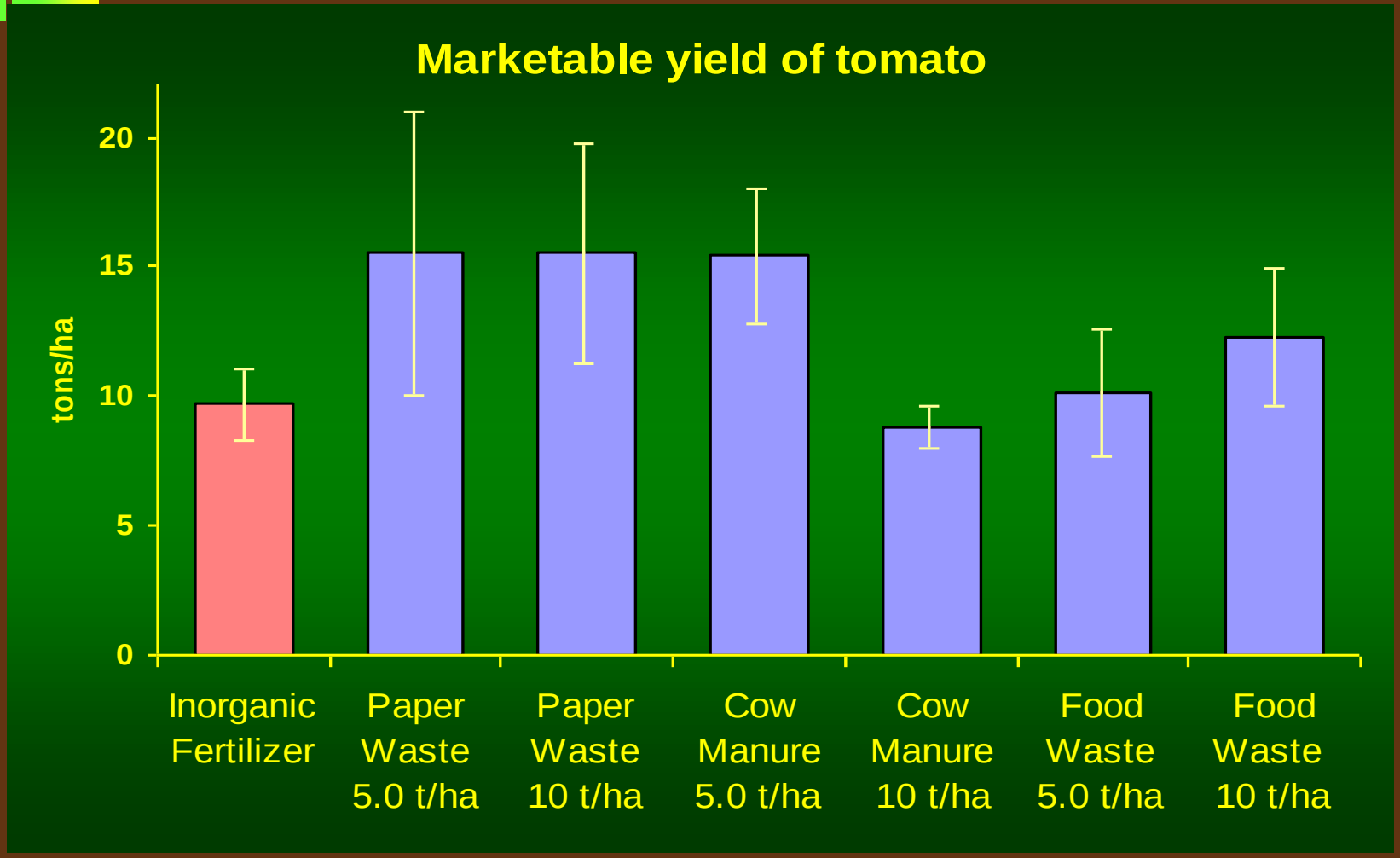
FULL-SCALE REACTOR

EFFECTS OF VERMICOMPOSTS ON PLANT GROWTH

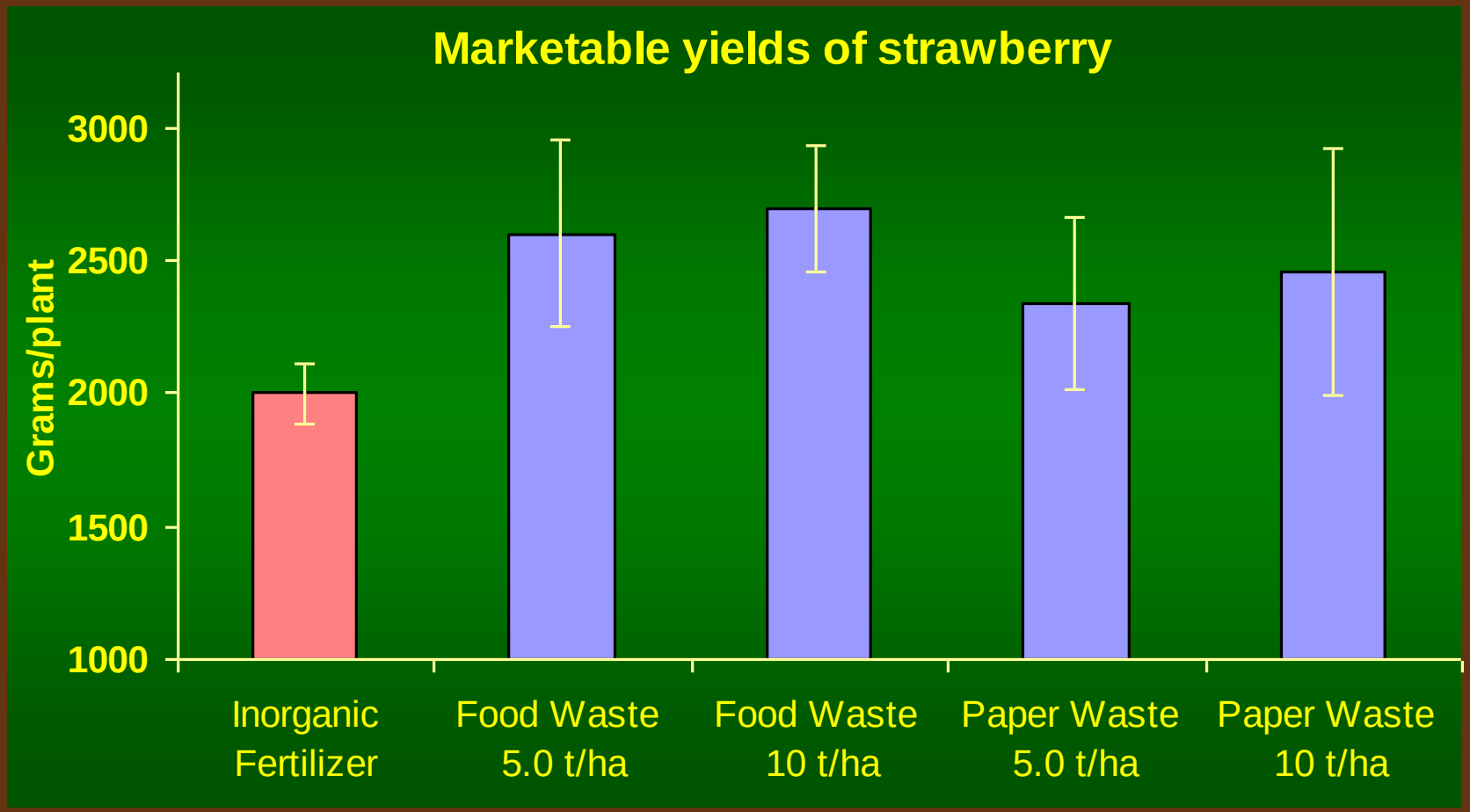
We have demonstrated very considerable increases in rates of germination, growth, flowering and fruiting and yields in crops grown with small substitutions or amendments with vermicomposts. These increases were usually independent of nutrient availability.

EFFECTS OF VERMICOMPOSTS ON TOMATO SEEDLING GROWTH

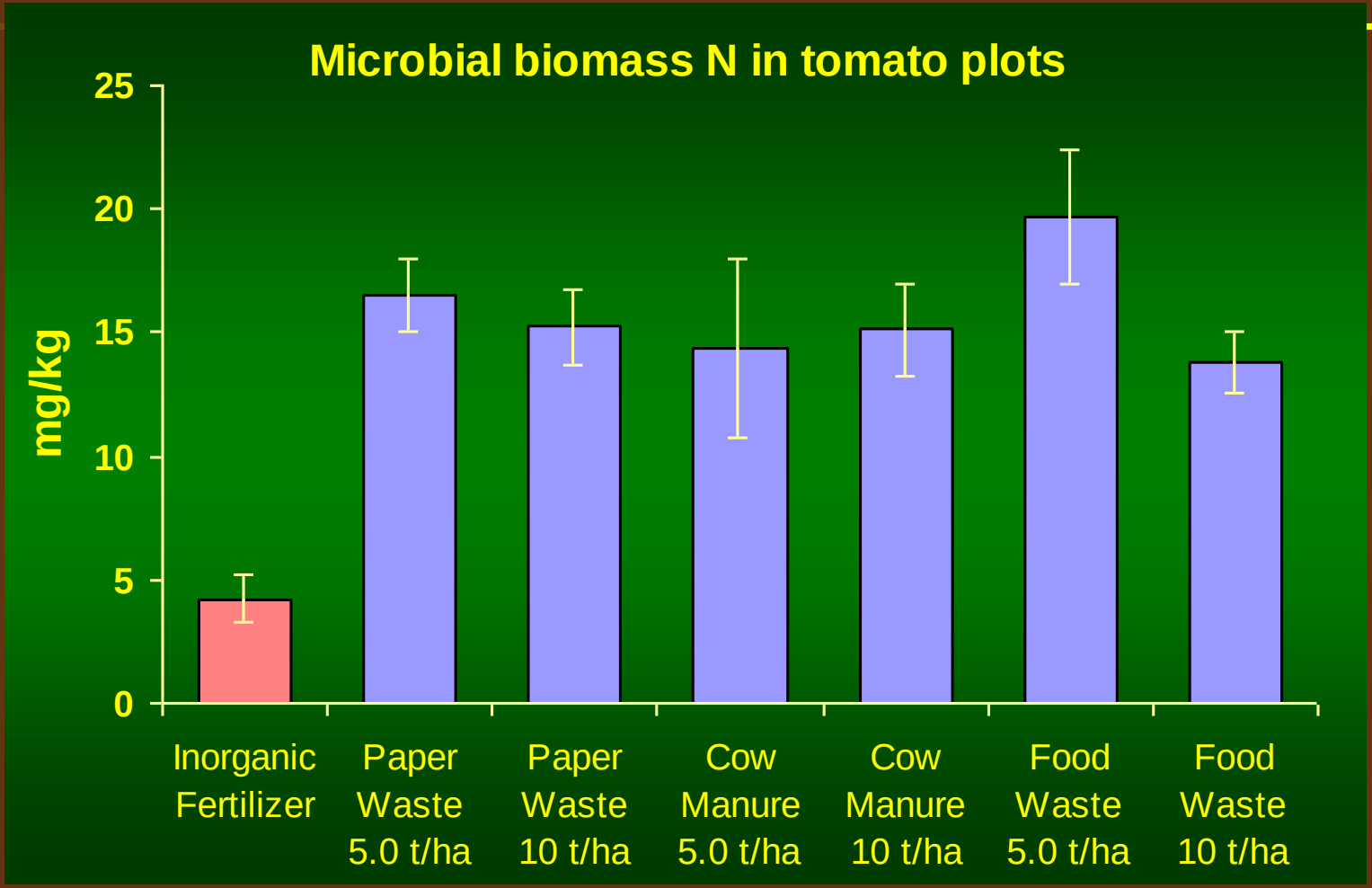
MARKETABLE YIELDS OF TOMATOES IN THE FIELD



MARKETABLE YIELDS OF STRAWBERRIES



MICROBIAL BIOMASS-N IN TOMATO FIELD EXPERIMENT



EVIDENCE FOR PLANT GROWTH REGULATORS IN VERMICOMPOSTS

- **SMALL SUBSTITUTIONS OF VERMICOMPOSTS INTO GROWTH MEDIA INCREASE PLANT GROWTH INDEPENDENT OF NUTRIENT SUPPLY**
- **VERMICOMPOSTS ARE EXTREMELY MICROBIALLY ACTIVE AND MICROORGANISMS PRODUCE PLANT GROWTH HORMONES**
- **AQUEOUS EXTRACTS OF VERMICOMPOSTS CAN INCREASE GROWTH INDEPENDENT OF NUTRIENTS**
- **BASE EXTRACTS OF HUMATES FROM VERMICOMPOSTS CAN INCREASE PLANT GROWTH INDEPENDENT OF NUTRIENTS**
- **GROWTH REGULATORS ADSORBED ONTO HUMATES IN VERMICOMPOSTS**
- **PLANT GROWTH PATTERNS E.G. STEM ELONGATION, ROOT GROWTH, FLOWERING PATTERNS ARE OFTEN CHANGED BY VERMICOMPOSTS**

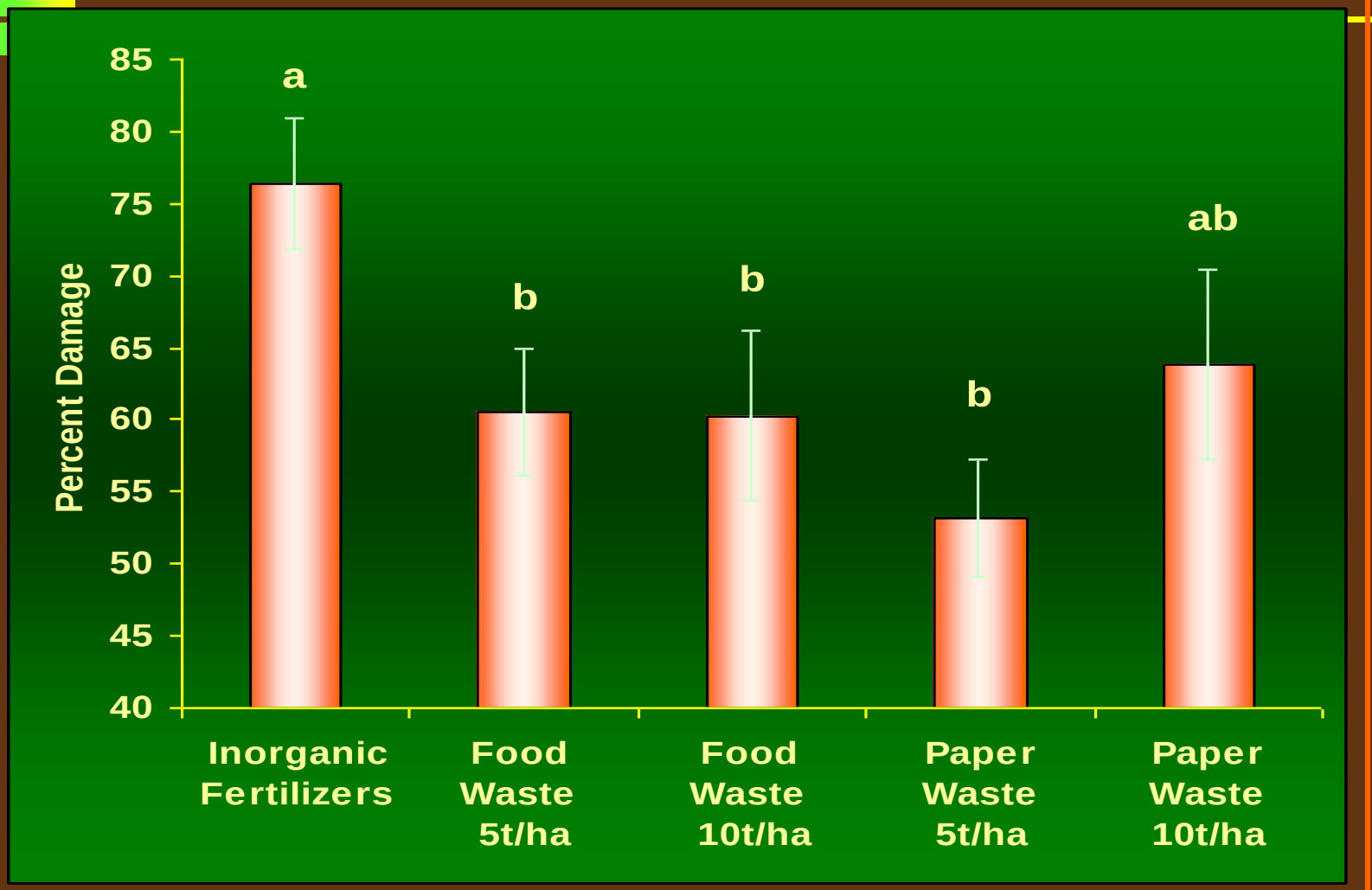
EFFECTS OF VERMICOMPOSTS AND VERMICOMPOST 'TEAS' ON PLANT DISEASES

- **Laboratory**
  - ***Pythium***
  - ***Rhizoctonia***
  - ***Plectosporium***
  - ***Phytophthora***
  - ***Fusarium***

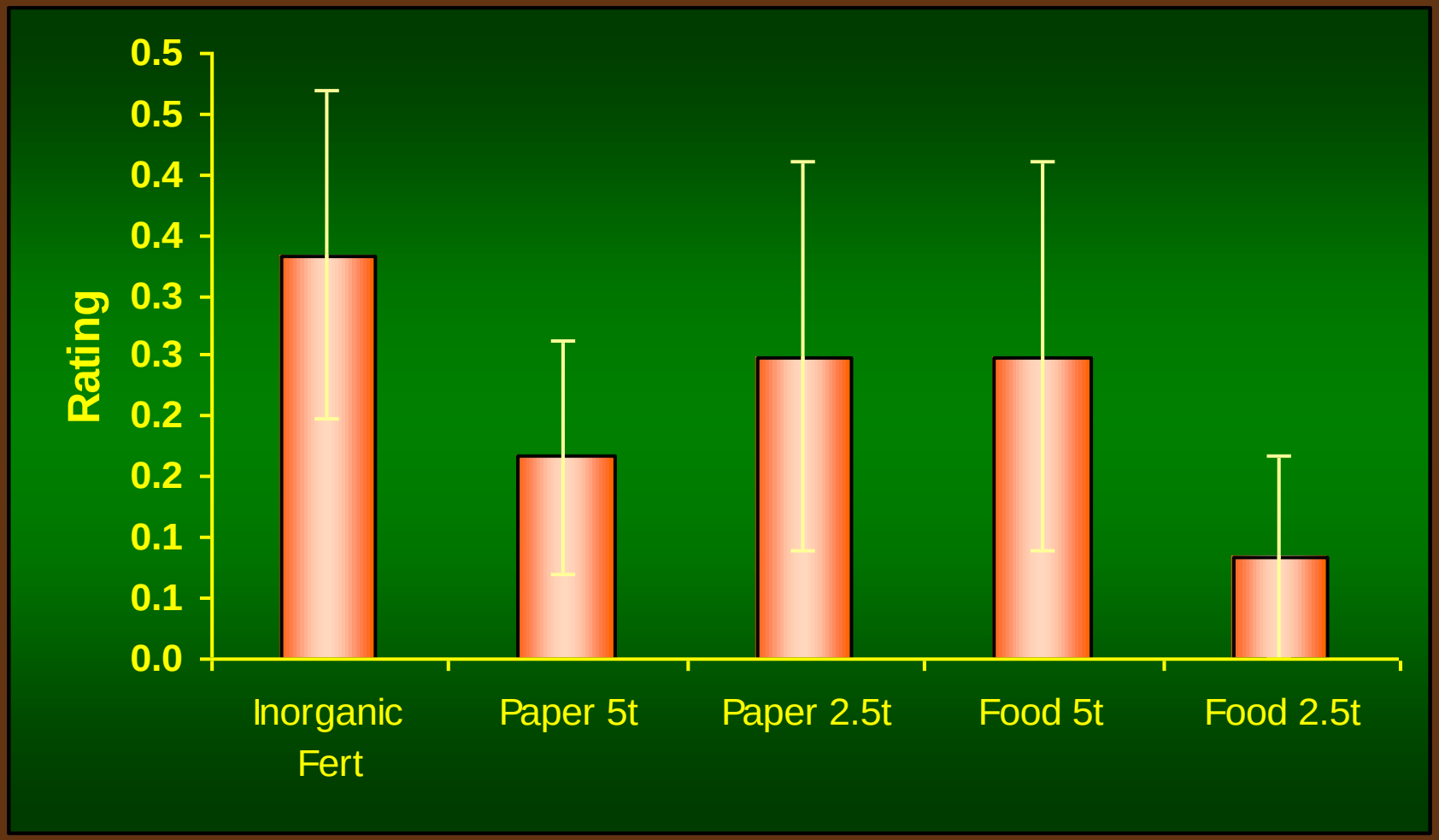
Field

- ***Verticillium***
- ***Phomopsis***
- ***Sphaerotheca***
- ***Uncinula necator***

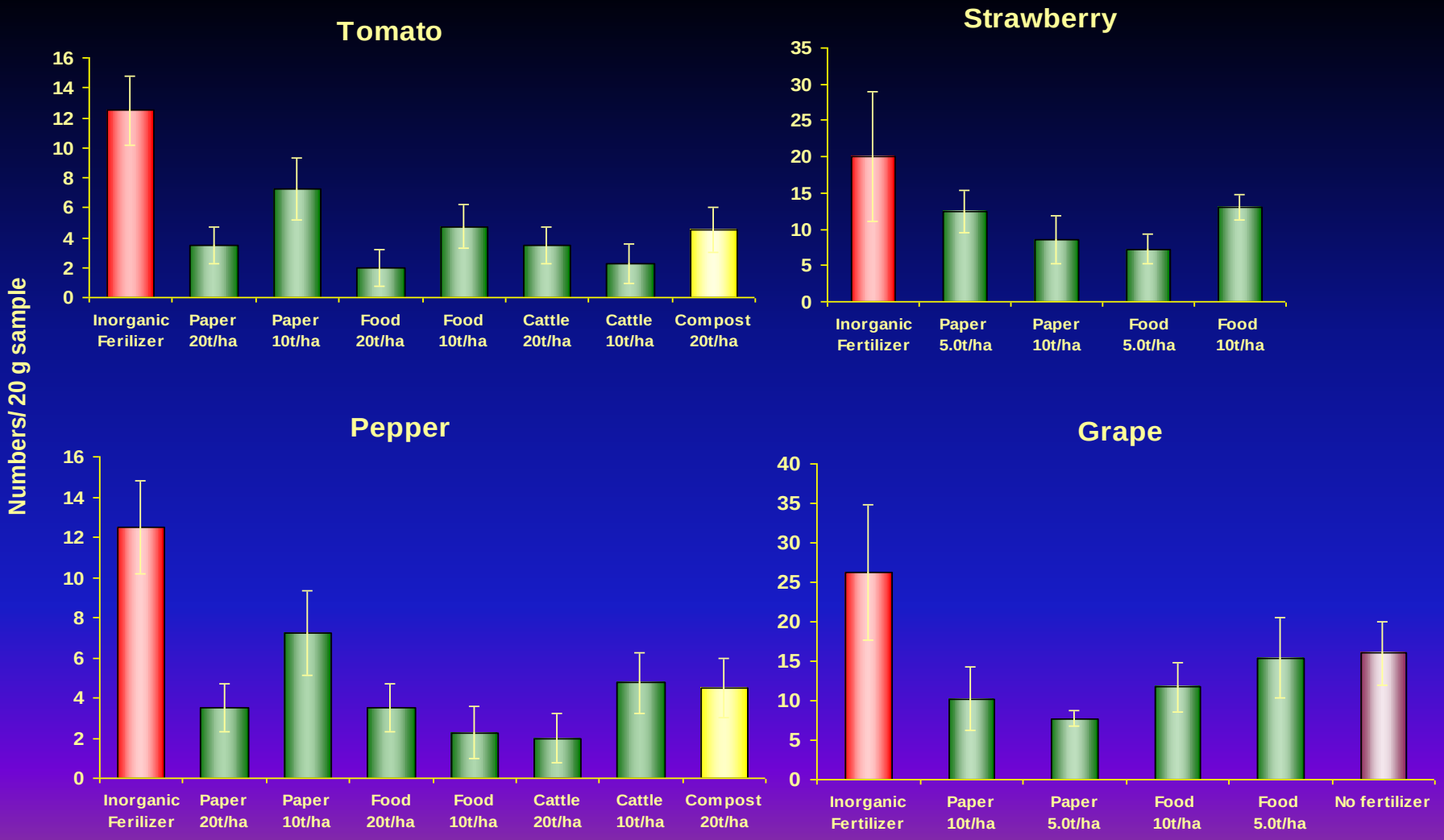
SUPPRESSION OF *VERTICILLIUM* ON STRAWBERRY BY VERMICOMPOSTS



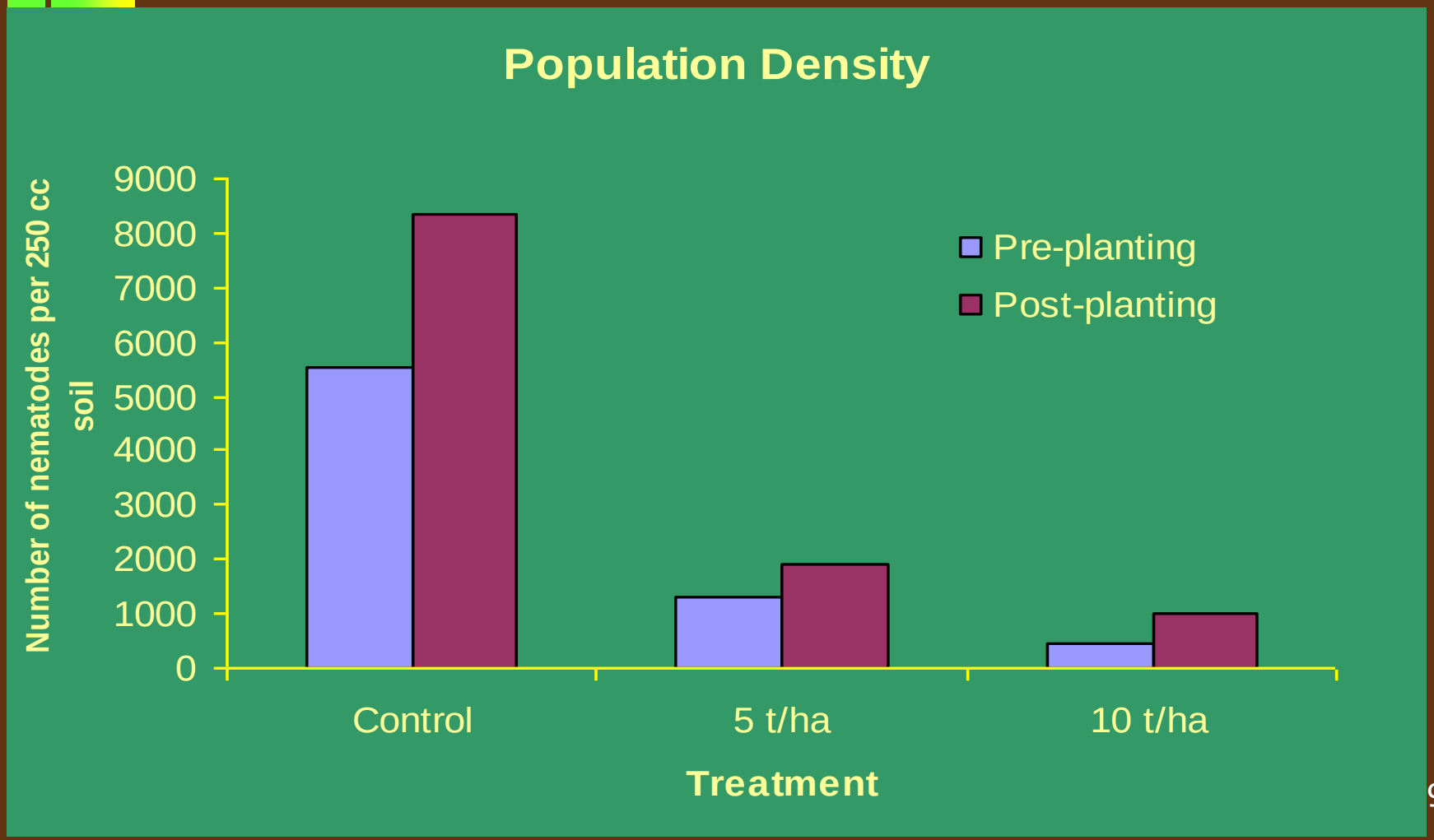
SUPPRESSION OF POWDERY MILDEW ON FIELD GRAPES BY VERMICOMPOSTS



PLANT PARASITIC NEMATODE POPULATIONS



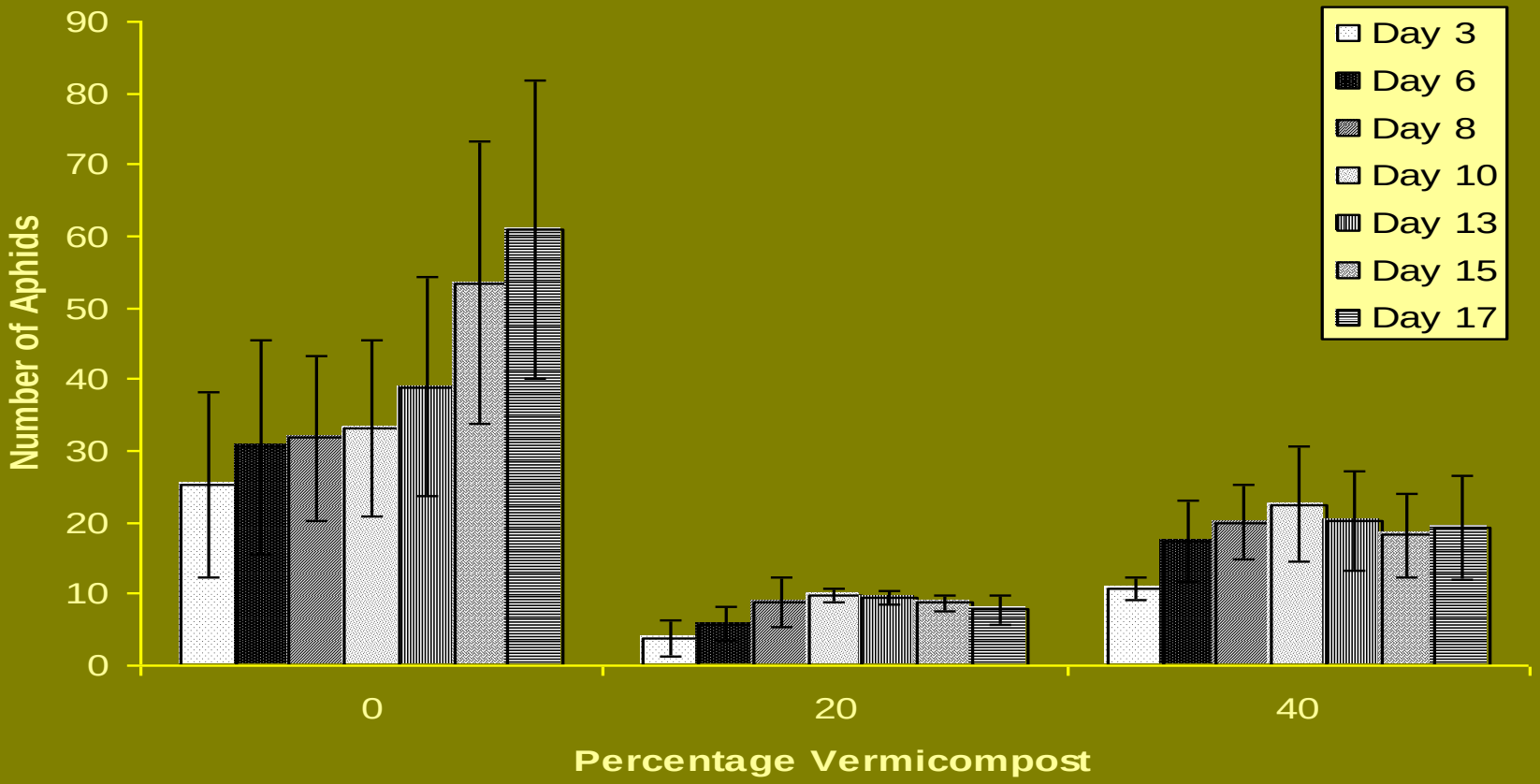
SUPPRESSION OF *MELOIDOGYNE* BY FOOD WASTE ON TOMATOES BY VERMICOMPOST



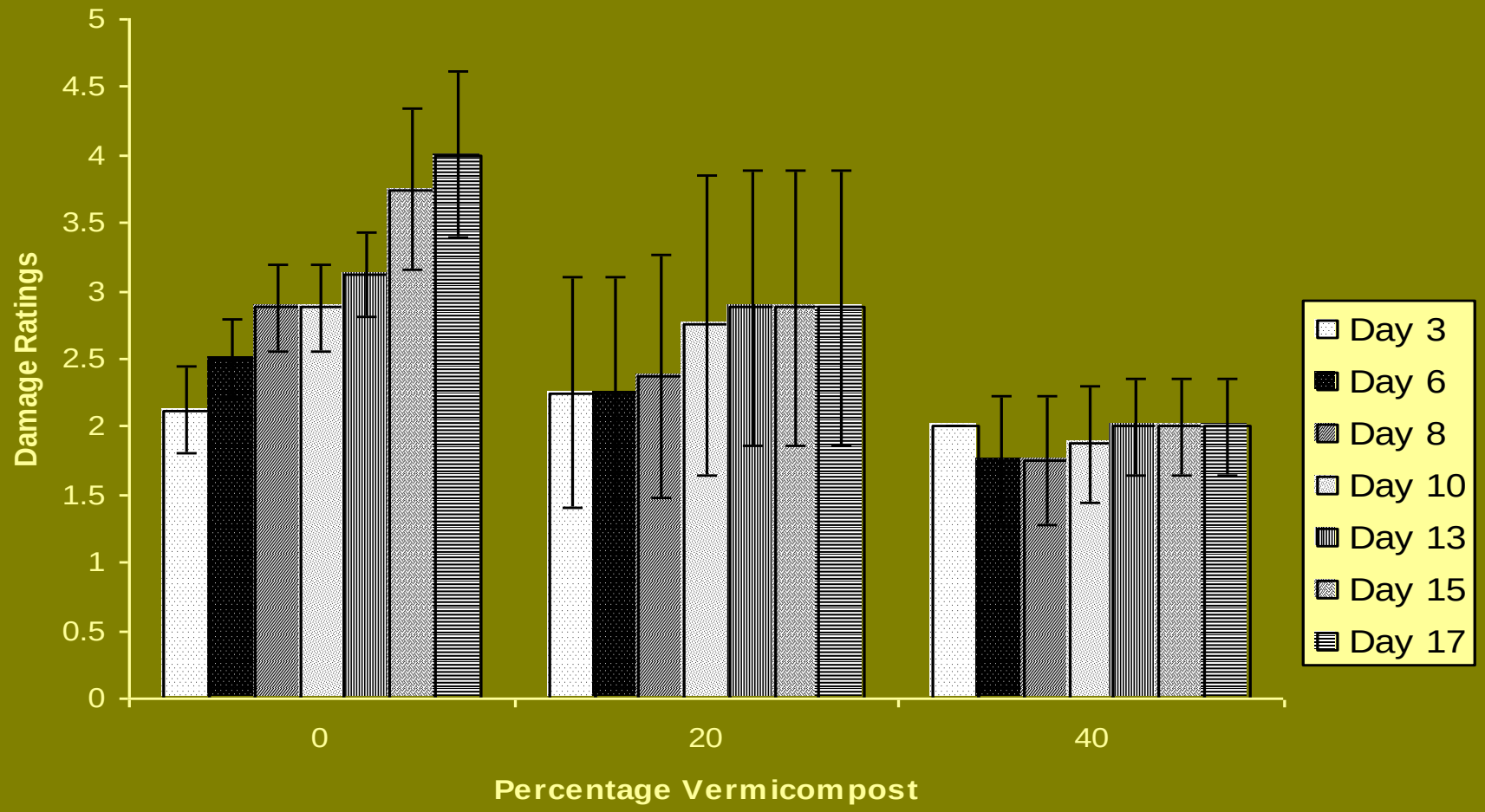
EFFECTS OF VERMICOMPOSTS ON ARTHROPOD PESTS

- SUCKING INSECTS
  - APHIDS
  - MEALY BUGS
  - TWO-SPOTTED SPIDER MITES
- CHEWING INSECTS
  - CABBAGE WHITE CATERPILLARS
  - CUCUMBER BEETLES
  - TOMATO HORNWORMS

EFFECTS OF VERMICOMPOSTS ON DEVELOPMENT OF APHID INFESTATIONS ON CABBAGE



EFFECTS OF VERMICOMPOSTS ON DAMAGE RATINGS OF TWO-SPOTTED SPIDER MITES INFESTATIONS ON EGGPLANTS



CONCLUSIONS ON ROLE OF VERMICOMPOSTS IN SUSTAINABLE AGRICULTURE

- Vermicomposts have great potential in horticulture and agriculture crop production due to production of plant growth regulators by the greatly increased microbial populations. These accelerate the germination, growth, flowering and yields of plants independent of nutrient supply.
- Vermicomposts also have potential, as solids or aqueous vermicompost extracts, in integrated pest management programs, since one application suppresses soil-borne plant pathogens, plant parasitic nematodes as well as numbers and reproduction of arthropod pests such as aphids, beetles and caterpillars.

CONCLUSIONS ON THE ROLE OF SOIL ECOLOGY IN SUSTAINABLE AGRICULTURE

- SUSTAINABLE AGRICULTURE DEPENDS ON INPUTS FROM BIOLOGICAL ORGANISMS INSTEAD OF CHEMICALS. THIS MAKES THE SOIL ECOLOGY PRINCIPLES AND INPUTS TO SUSTAINABLE AGRICULTURAL SYSTEMS A CRITICAL COMPONENT.